VASCULAR AND ENDOVASCULAR TECHNIQUES

Thomas L. Forbes, MD, Section Editor

Stent graft modification with mini-cuff reinforced fenestrations for urgent repair of thoracoabdominal aortic aneurysms

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Fenestrated endografts require 6 to 8 weeks for device customization, and off-the-shelf devices are not yet available and may not be of easy access for urgent repair of complex aneurysms. We describe a technique of stent graft modification in a high-risk male patient with two prior open aortic repairs, end ileostomy, and a rapidly enlarging 10-cm supra-graft type IV thoracoabdominal aortic aneurysm. A Z-stent thoracic stent graft was modified on-site using mini-cuff reinforced fenestrations to incorporate the visceral arteries and improve overlap at the side branch attachment sites. After successful repair, the patient was discharged at 4 days without complications and with patent branched stent grafts without endoleak. On-site modifications of endografts may allow urgent endovascular treatment of complex aortic aneurysms in high-risk patients who are not good candidates for open repair or who do not have access to manufactured fenestrated devices. (J Vasc Surg 2011;54:1522-6.)

The ability to use endovascular techniques to treat symptomatic or ruptured complex aortic aneurysms hinges on at least two major challenges. First, fenestrated and branched stent grafts that incorporate the visceral arteries are currently not approved for commercial use in the United States, and device customization requires a wait period of 6 to 8 weeks.[1,2] Based on predictable anatomic location of the visceral arteries, "off-the-shelf" devices using standardized designs will allow treatment of >80% of pararenal and thoracoabdominal aortic aneurysms (TAAAs).[3,4] However, these devices are not yet available and may not be of easy access to centers with limited inventory or to patients necessitating urgent repair. Second, because the repair needs to be performed expeditiously, patients need to be stable to withstand the time needed for device implantation.

Stent graft modifications have been described using reinforced fenestrations and presewn cuffs.[5-7] This technique may allow treatment of patients with symptomatic, rapidly expanding, or contained ruptured aneurysms who cannot await the time required for customization, do not have access to manufactured fenestrated devices, or in whom an off-the-shelf design is not applicable. A limitation of modified fenestrations as previously described is the lack of a reinforcing nitinol ring, which is currently used for manufactured devices. Instead, modified fenestrations are reinforced by a radio-opaque wire, but this may not provide adequate seal if the target vessel originates from the aneurysm sac. We describe a novel technique of stent graft modification with mini-cuff reinforced fenestrations in a patient with a rapidly enlarging TAAA.

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TECHNIQUE

A 74-year-old male patient presented with a rapidly enlarging 10-cm supra-graft type IV TAAA (Fig 1, *A*). The patient underwent two prior open abdominal aortic aneurysm repairs, including repair of a juxtarenal para-anastomotic aneurysm with aortoiliac and left renal artery bypass grafts (Fig 1, *B*). His medical history included morbid obesity, ileostomy, hypertension, hyperlipidemia, severe ischemic cardiomyopathy, and congestive heart failure with ejection fraction of 30%. Urgent endovascular repair was performed using a modified endograft with three fenestrations to incorporate the celiac axis, superior mesenteric artery (SMA), and left renal artery graft. The patient had no complications and was dismissed home on the fourth postoperative day. A computed tomography angiography confirmed successful aneurysm exclusion, no endoleak, and widely patent branched stent grafts (Fig 1, *C*).

Device modification. A tapered TX2 38-mm × 202-mm stent graft (Cook Medical, Bloomington, Ind) was modified on-site under strict sterile technique with reinforced fenestrations (Fig 2) and a diameter-reducing

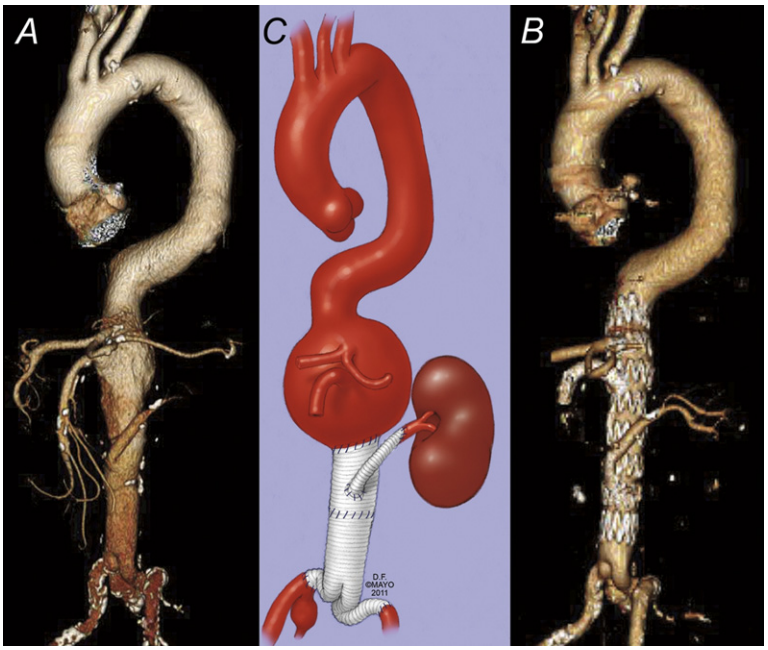

Fig 1. Computed tomography angiography shows a 10-cm type IV thoracoabdominal aortic aneurysm **(A)** on a patient with prior aortic repair and left renal artery bypass graft **(B)**. Repeat computed tomography angiography after urgent endovascular repair with modified fenestrated endograft showed successful aneurysm exclusion, no endoleak, and patent branched stent grafts **(C)**.

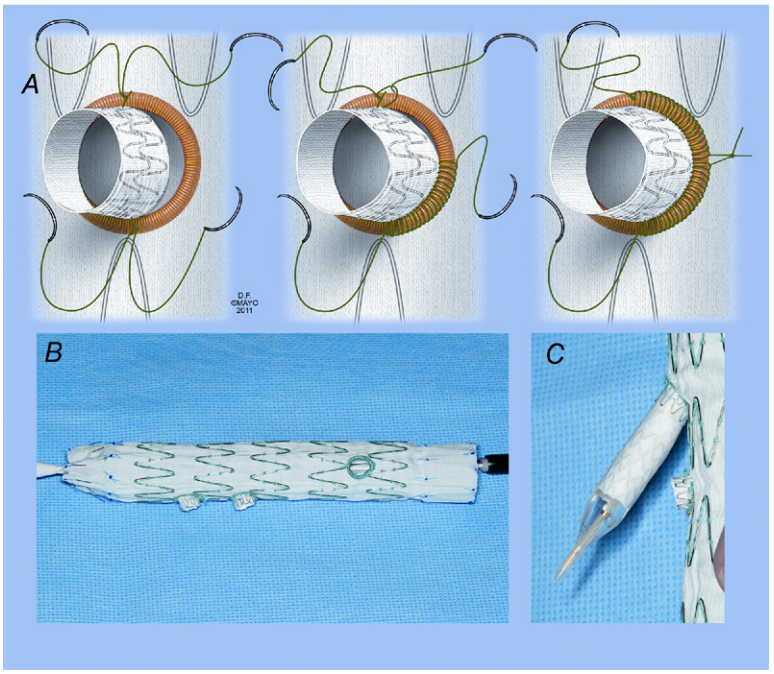

Fig 2. Technique of stent graft modification with mini-cuff reinforced fenestration. A 3- to 5-mm mini-cuff is fashioned from a Viabahn stent graft, which is cut using scissors in a straight, up-going or down-going fashion to accommodate the desired side branch configuration. The mini-cuff and a gold radio-opaque wire, which is obtained from the Amplatz Goose Snare Kit, are sewn into the fenestration with locking 5-0 Ethibond sutures **(A)**. This technique provides excellent suture handling, hemostasis, and attachment, and is the technique of choice by the manufacturer for reinforcement of fenestrations. Note that the modified TX2 stent graft included two mini-cuff reinforced fenestrations for the celiac and superior mesenteric artery, and a standard fenestration for the left renal bypass graft **(B)**. The mini-cuff reinforced fenestrations are bridged using iCAST-covered stents **(C)**.

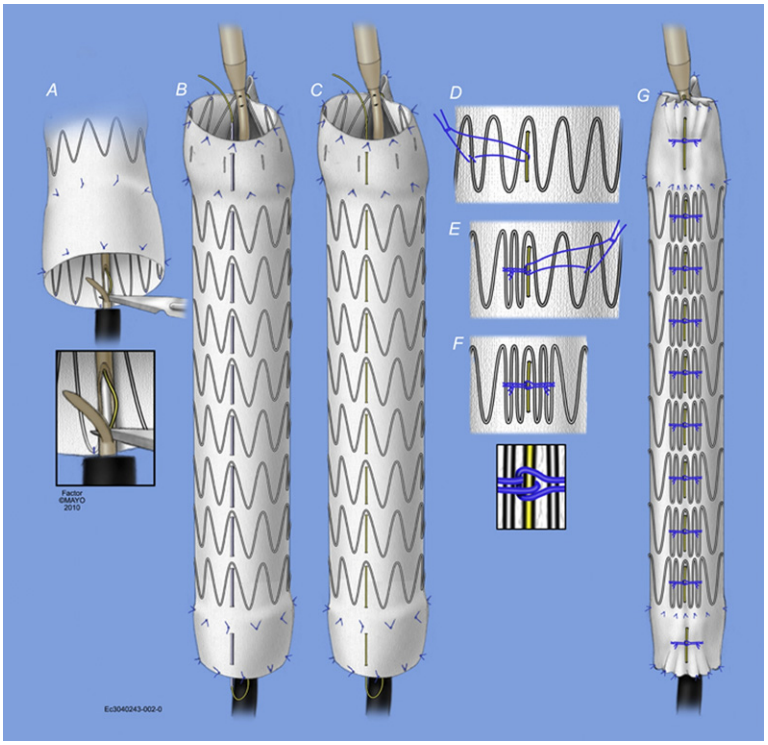

Fig 3. A diameter-reducing wire is added to facilitate implantation of the modified TX2 stent graft. The nitinol wire used for the diameter-reducing wire is obtained from the inner cannula of the stent graft, which is opened with a scalpel **(A, inset)**. One of the three nitinol wires is retrieved and rerouted posteriorly through and through the fabric of the stent graft using a long 22-gauge spinal needle **(B)**. Once the wire is in place **(C)**, the Z stents are constrained using loops of prolene. The first loop is placed around the stainless steel wire **(D)**, and the second loop is routed around the first prolene loop **(E)**, with careful attention not to place the suture through the first prolene loop **(F, inset)**. The nitinol wire is then relocated into the cannula **(G)**.

wire (Fig 3), as previously described.[8] The celiac axis and SMA, which originated from the aneurysm sac, were incorporated using fenestrations reinforced by an 8-mm Viabahn stent graft (W. L. Gore, Flagstaff, Ariz), which was fashioned into 3-mm to 5-mm length mini-cuffs (Fig 2, *A*). The mini-cuff and a radiopaque wire were sewn into the fenestration of the aortic stent graft using locking 5-0 Ethibond sutures (Fig 2, *A*). Because the left renal artery graft originated from the sealing zone, a mini-cuff was not added (Fig 2, *B*). Time required for device modification was 150 minutes.

Implantation. The procedure was performed under general endotracheal anesthesia after placement of a spinal drain and systemic heparinization. Following selective catheterization of target vessels, the modified stent graft was oriented extracorporeally, introduced via the right femoral approach, and deployed. Fenestrations and target vessels were catheterized without difficulty, using a left brachial approach for the celiac axis and a left femoral approach for the SMA and left renal graft. Hydrophilic sheaths (7 Fr) were advanced into the target vessels over stiff 0.035-inch guidewires, followed by removal of the diameter-reducing wire and expansion of the aortic stent graft. Each vessel was sequentially stented using iCAST stents (Atrium Medical, Hudson, NH; Fig 2, *C*). Because of significant angulation in the proximal SMA, this branch was constructed using multiple stents (Fig 4, *A*). First, a 10-mm × 60-mm self-expandable Fluency stent graft (Bard, Covington, Ga) was deployed extending from just beyond the mini-cuff to the proximal SMA (Fig 4, *B*). Next, a 10-mm × 38-mm iCAST stent was deployed and flared, extending from across the mini-cuff fenestration into the Fluency stent graft with >3 cm overlap (Fig 4, *B* and *C*). Finally, a Protégé 12 mm × 40 mm self-expandable stent (ev3, Plymouth, Minn) was added distally to reinforce the Fluency stent graft and prevent kink (Fig 4, *B*). Selective completion angiography revealed patent branches and no endoleak (Fig 5).

DISCUSSION

Open repair of TAAAs is associated with mortality rates of 5% to 14% in referral centers.[9] However, Ridberg reported alarming results in the community, with 30-day mortality of 19% for elective and 48% for urgent or emergent repair.[10] Modified fenestrated endografts can be used to incorporate the visceral arteries and treat patients who

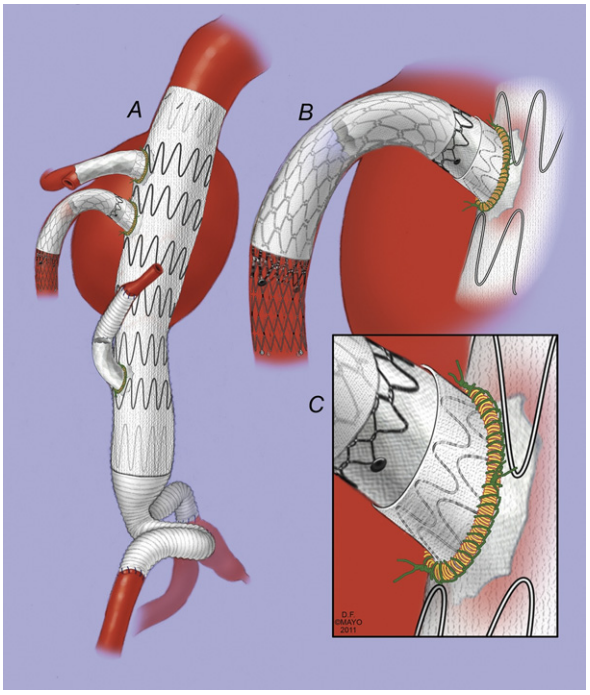

Fig 4. Illustration of the modified fenestrated stent graft **(A)** with two mini-cuff reinforced fenestrations and a standard fenestration. Note that the superior mesenteric artery required a combination of self-expandable stent distally and a balloon-expandable stent proximally because of significant angulation **(B)**. The mini-cuff reinforced fenestration was bridged with a balloon-expandable stent graft, which was flared to optimize seal, similar to what is performed using standard fenestrations **(C)**.

present with symptomatic or contained ruptured complex aortic aneurysms and do not have access to manufactured devices.[5] Although this may be a future "niche" indication for modified endografts, its current use should be strictly limited to compassionate treatment of high-risk patients who are not candidates for open surgical or hybrid repair.

It is imperative that physicians involved with these techniques are familiar with advanced concepts of device design, modifications, implantation, and "bail out" maneuvers. The most important component of the technique is a detailed anatomic analysis of the extent of aortic disease and preprocedure planning, which is accomplished with advanced three-dimensional imaging and centerline software. We currently use a diameter-reducing wire for all modifications (Fig 3), which improves flow into target vessels during manipulations and allows longitudinal and rotational movement of the aortic stent graft in case of misalignment between the fenestration and the target vessel. Reinforced fenestrations are selected for vessels originating from the seal zone or from areas where the gap between the deployed endograft and the aortic wall bearing the target vessel is <10 mm. If the gap is >10 mm, a mini-cuff is added to increase seal zone at the attachment site (Fig 4, *A*). A disadvantage of adding a mini-cuff is the limited space between the endograft and the aortic wall, potentially making catheterization of side branch more difficult.

This novel technique of reinforcement with mini-cuff offers an alternative to standard reinforcement with nitinol rings, potentially decreasing endoleak rates in patients with

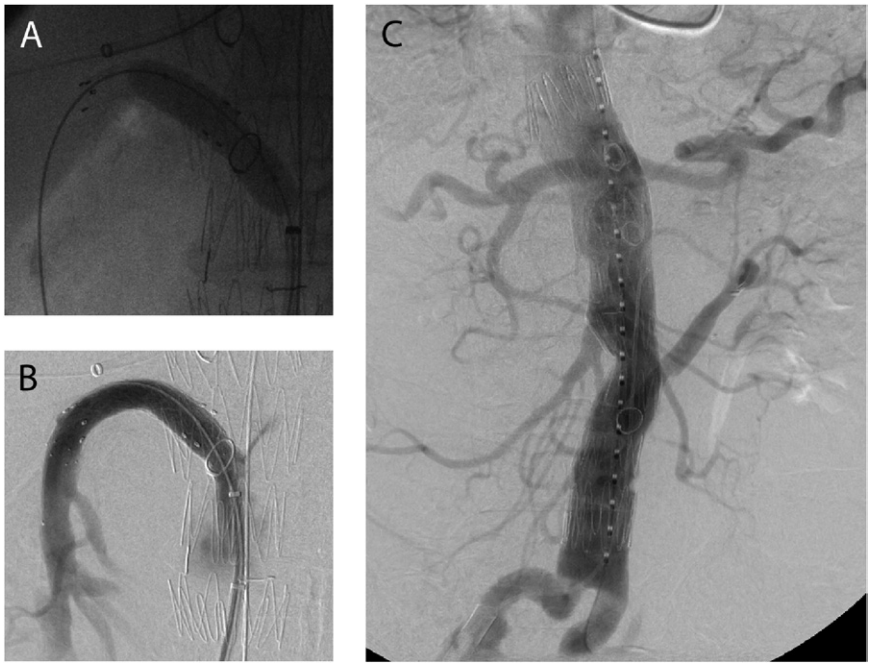

Fig 5. Placement of bridging stents in the superior mesenteric artery (SMA) using a self-expandable Fluency stent graft distally **(A)** and a balloon-expandable iCAST stent proximally **(B)** into the mini-cuff reinforced fenestration. Selective SMA angiography **(B)** and completion aortography confirmed widely patent stent grafts without endoleak **(C)**.

a large aneurysm sac. Our preference has been to use locking 5-0 Ethibond to reinforce fenestrations and to anastomose the mini-cuff, similar to the technique used by the manufacturer. This technique offers excellent suture handling, hemostasis, and secure attachment. We have used Viabahn stent grafts to fashion the mini-cuffs because of their low profile, ease to resheath, and self-expandable design, which allows collapsing the stent during resheathing and immediate expansion once released. We have not encountered difficulty to resheath mini-cuffs using this technique, provided that no more than three mini-cuffs are used and that mini-cuffs are not be placed in close proximity.

Selection of the matting stent should take into consideration the type of attachment (eg, nitinol ring, mini-cuff, or long cuff) and vessel angulation. Standard fenestrations reinforced by nitinol ring and mini-cuffs provide minimal overlap and therefore require bridging with a balloon-expandable covered stent (Fig 2, *C*), which has greater radial force but lacks flexibility. Self-expandable stents are not ideally suited to bridge standard fenestrations or mini-cuffs because of risk of component separation due to insufficient overlap. However, longer cuffs (>1.5 cm) may be bridged by self-expandable stent grafts, as described by Jim and associates, and used by Chuter and Greenberg with manufactured devices.[1,2,6] Therefore, a limitation of the mini-cuff technique as herein described is that, in patients with tortuous or angulated vessels, a hybrid stent (self-expandable combined with balloon-expandable) may be needed, such as the SMA in the case herein presented, which is not ideally suited for use of more rigid balloon-expandable stents (Fig 4, *A*). The durability of self-expandable stents combined with balloon-expandable stents has not yet been determined, but there are concerns about development of kinks, fractures, or component separations.

CONCLUSION

Modified fenestrated stent grafts are feasible and useful to treat patients with symptomatic, rapidly enlarging, or contained ruptured TAAAs. The use of mini-cuff reinforced fenestrations allows better seal at the attachment site, potentially reducing the risk of endoleak, without adding to the bulk of the device. This technique may expand the indications of endovascular treatment to patients who need urgent repair, are unfit for open surgery, and do not have access to a manufactured fenestrated device.

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